Climate Change & NASA

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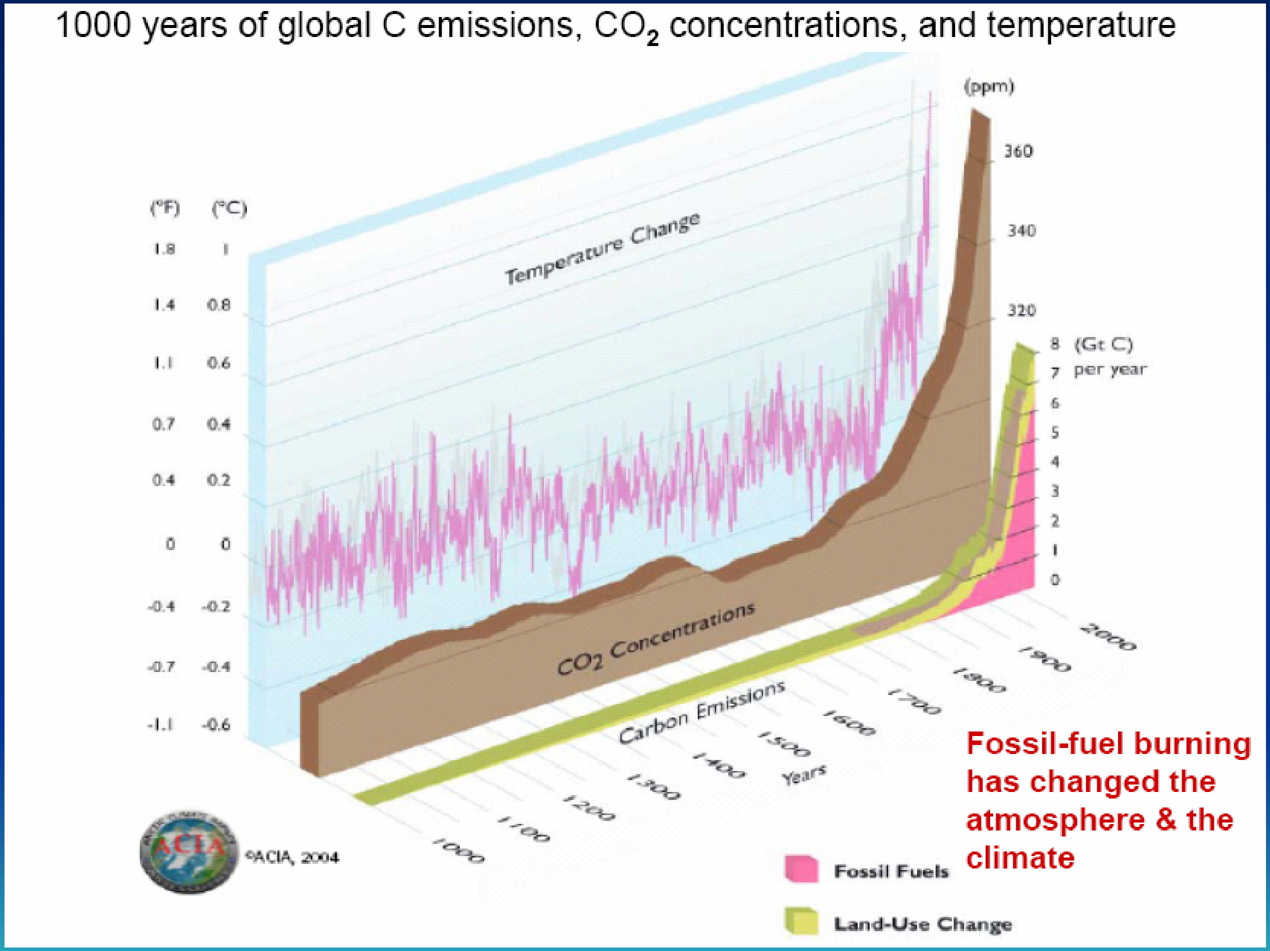
Climate Change & NASA

OVERVIEW

- Climate Change and P2 (Green House Gases)
- NASA-HQ activities - Climate Change
- Risk Effects of Climate Change on NASA: Types of Risks (e.g., Regulatory Risk, Supply Chain Risk, Product & Technology Risk, Physical Risk)
- Reducing NASA's Risk Exposure to Climate Change

Climate Change and Pollution Prevention

Climate Change > Temperature > Greenhouse Gases > CO_2 Concentration > Carbon Emissions



J. P. Holdren (2006) AAAS Science & Technology Policy Forum: “The Economic, Environmental, & National Security Challenges of Energy Supply and the Role of Science & Technology in Addressing Them” http://www.aaas.org/spp/rd/Forum_2006/holdren.pdf

Climate Change and P2

(Greenhouse Gases)

- Climate Change computer models:

  Data input “Greenhouse Gases” (typically, Greenhouse Gases = CO_2 equivalents)

- Climate Change proposed mitigation efforts:

  Reducing CO_2 equivalents of Greenhouse Gases

- Applying P2 Hierarchy to Greenhouse Gases:

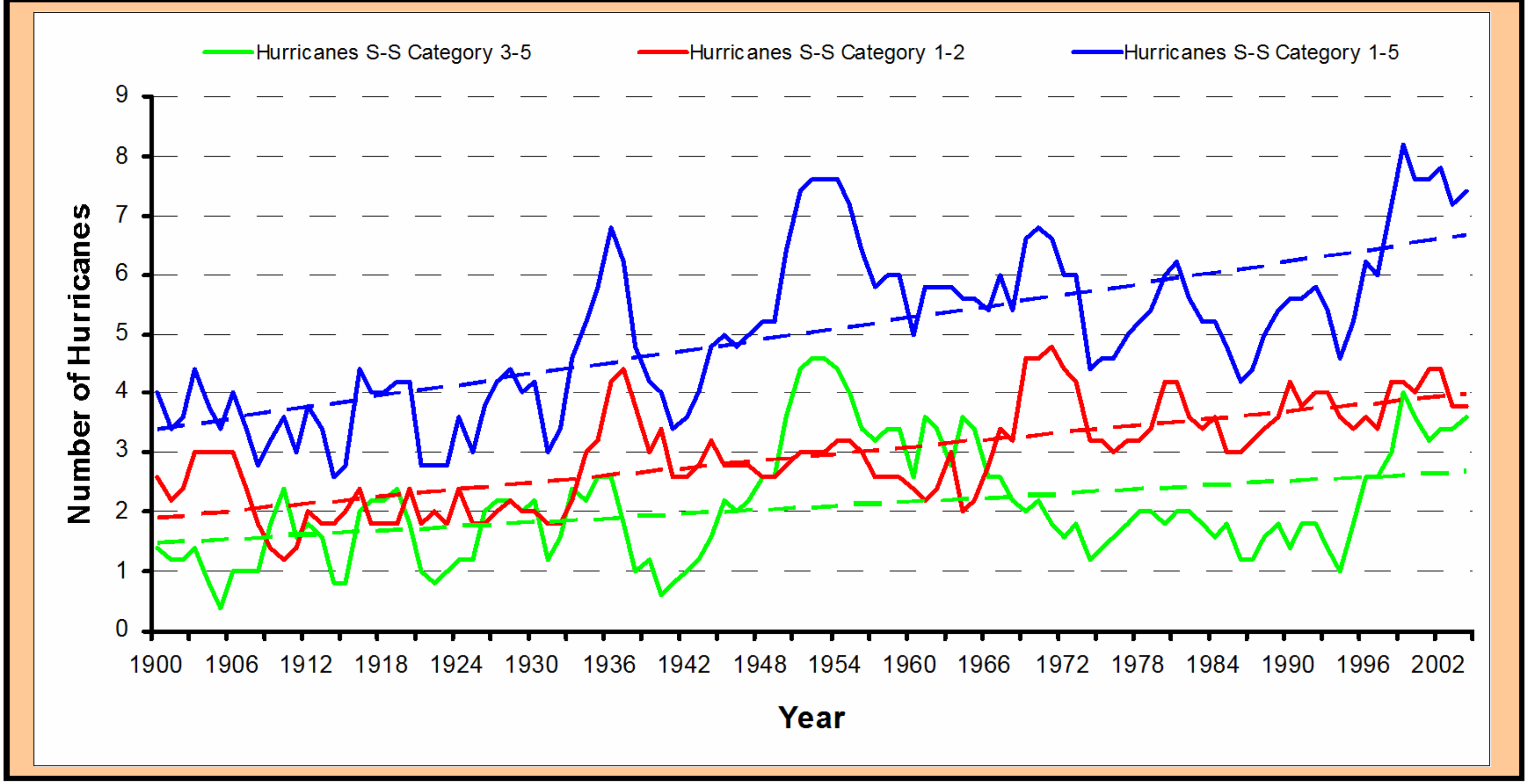
  Reduce, recycle and reuse, treatment, dispose of Greenhouse Gases

NASA-HQ activities

- NASA-HQ Office of Infrastructure & Administration (I&A):
  - Identified Climate Change and Regional Climate Variability as “Risks to NASA”
- I&A Risks:
  - Managed in a Risk Management process

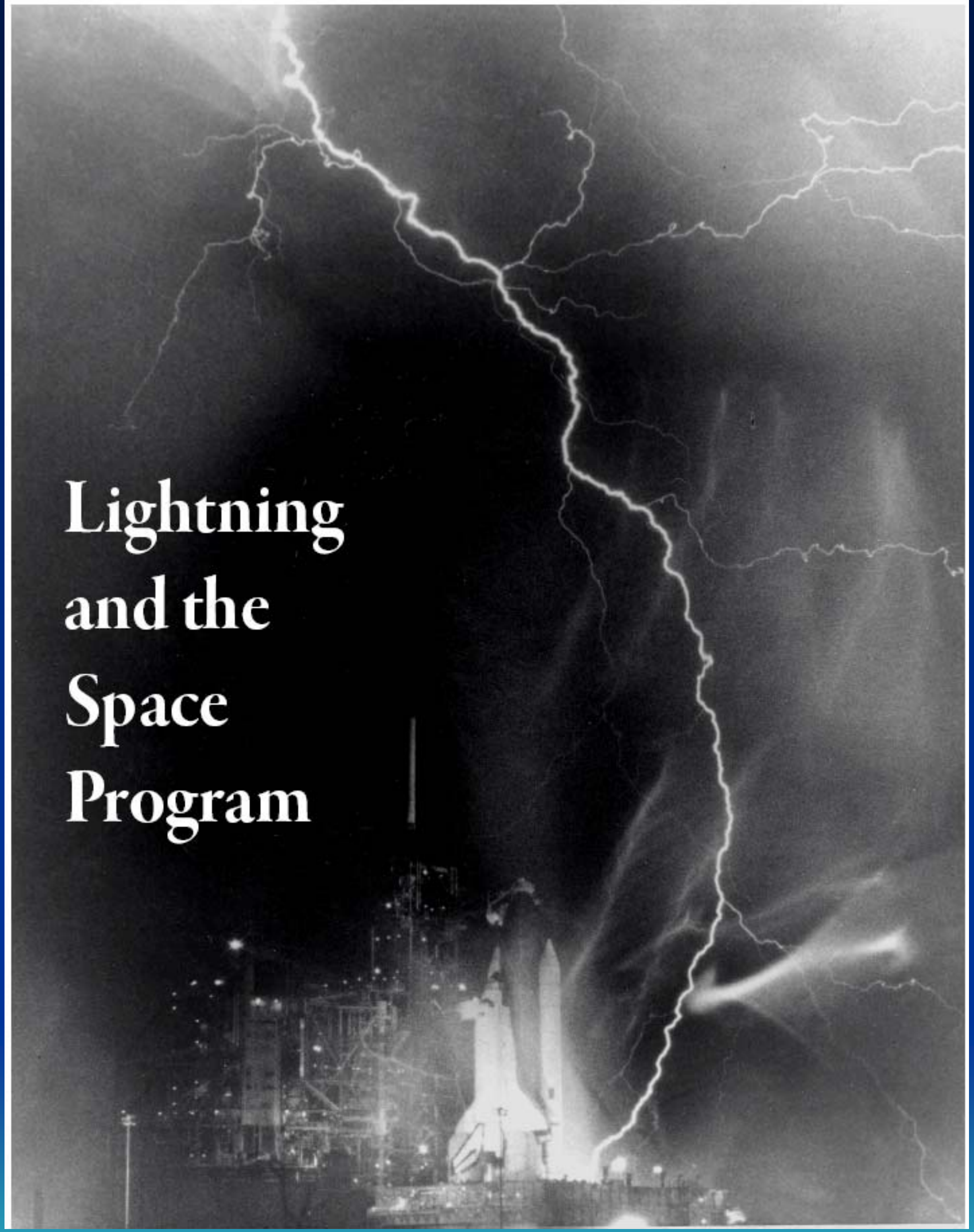
EXAMPLES – RISK EFFECTS OF CLIMATE CHANGE ON NASA

Figure 3.9: Trends in Hurricane Genesis in the North Atlantic Basin (5-year moving average)



Source: Derived from HURDAT "best track" data (NOAA National Hurricane Centre)

Climate Risk Management Limited (2005) "Report for Association of British Insurers: Financial Risks of Climate Change"


Lightning
and the
Space
Program

Climate Related Mission Impacts
(Extreme Events – severe weather - hail)

AT LAUNCH Pad 39A, the external tank attached to orbiter Atlantis shows damage from hail during a strong thunderstorm that passed through Kennedy Space Center on Feb. 26.

Swiss Re (July 2000) Twister! Professional Reinsurer's Perspective

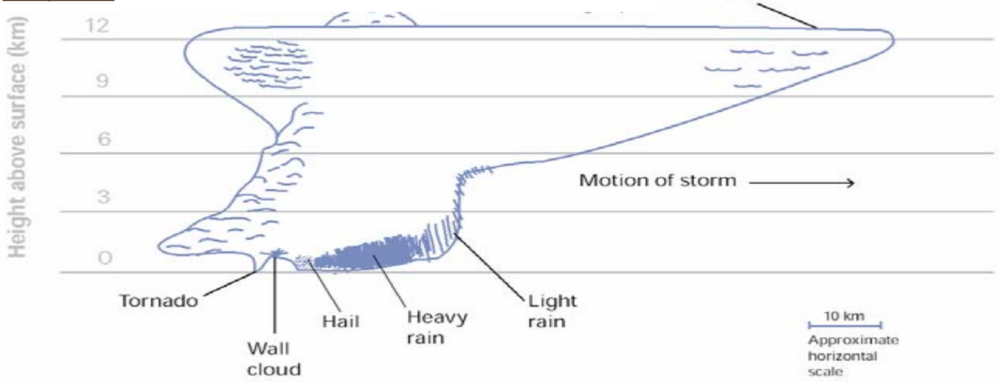
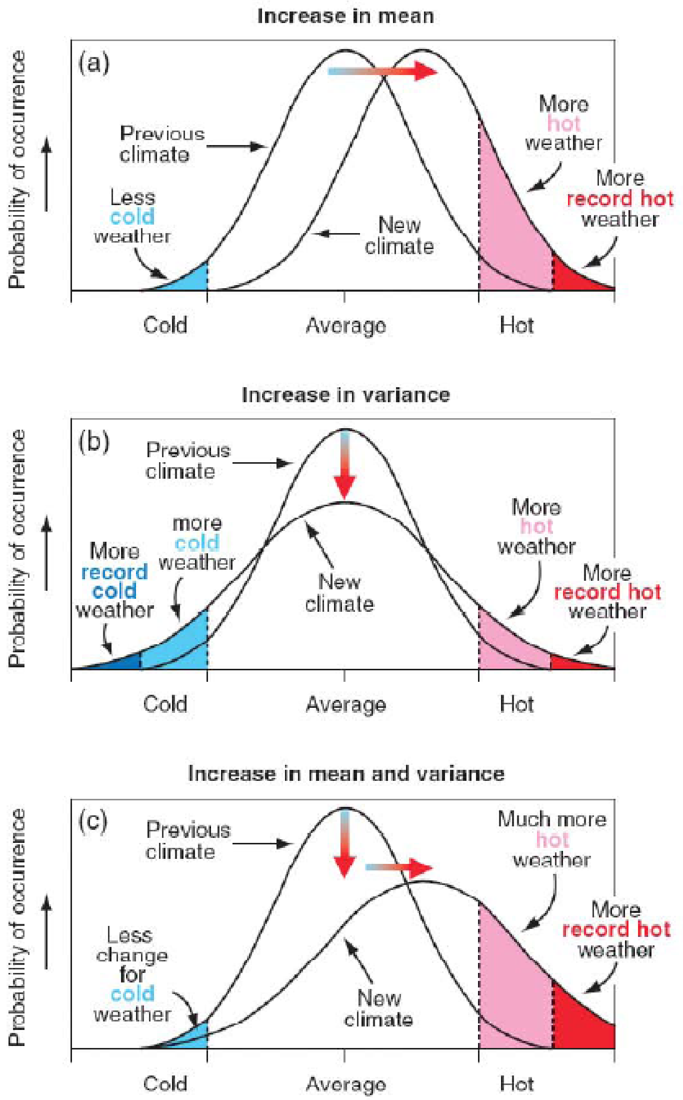


Figure 1.4 Climate Change Alters the Distribution of Weather Events

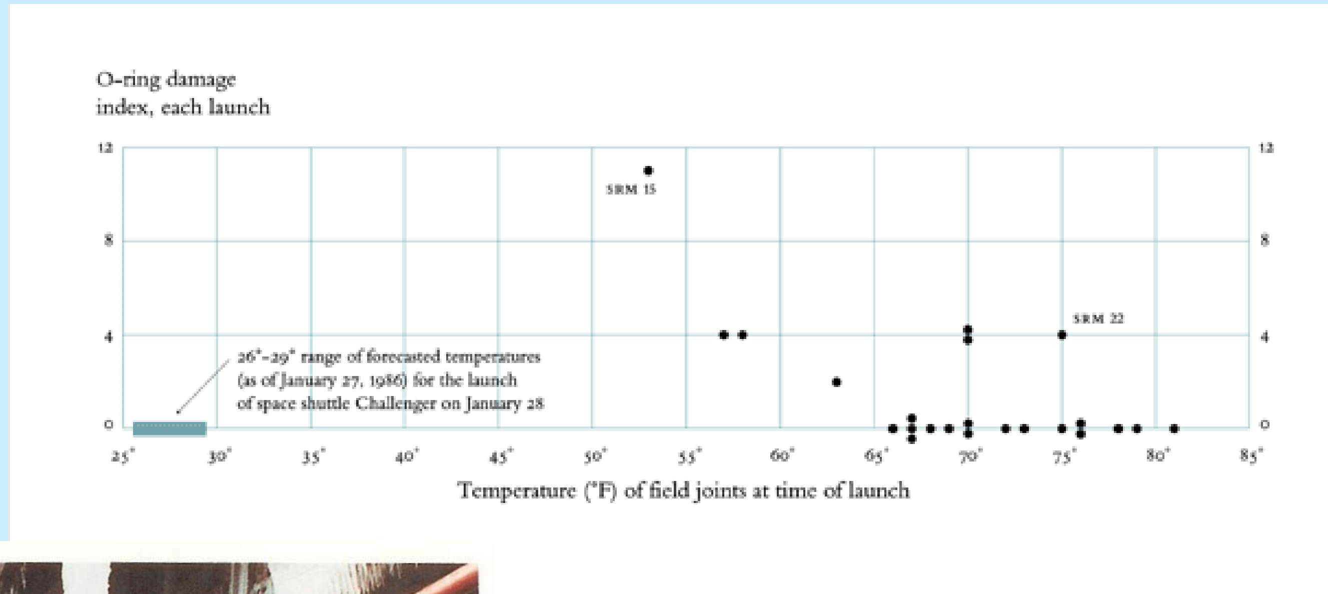


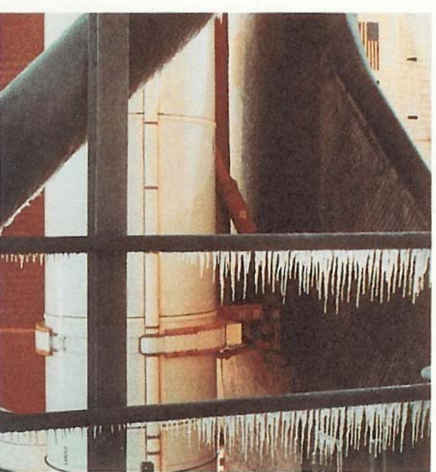
Schematic showing the effect on extreme temperatures when (a) the mean temperature increases, (b) the variance increases, and when (c) both the mean and variance increase. The current climate appears to be a hybrid of (b) and (c); that is, the average temperature is warming and more hot and cold anomalies are occuring.
Image: IPCC 2001

Harvard Medical School (2005) Climate Change Futures Health, Ecological and Economic Dimensions
http://www.climatechangefutures.org/pdf/CCF_Report_Final_10.27.pdf

CHALLENGER AND

LAUNCH SITE WEATHER CONDITIONS





From: E. Tufte (1997) Visual Explanations

CLIMATE CHANGE AND SPACE TRANSPORTATION: INTERACTIONS AND IMPACTS

This diagram conceptualizes how weather characteristics (e.g., temperature, precipitation) contribute to weather-related impacts (e.g., freeze-thaw cycles, reduced visibility, tropical storms) which in turn affect space transportation infrastructure, operations, and space exploration equipment.

WEATHER CHARACTERISTICS

- **Temperature**
- **Precipitation:** *rain, hail, snow, freezing rain, dew, hoarfrost*
- **Wind:** *speed, direction*
- **Sky Conditions:** *sunshine, cloudiness, fog, smog, lightning*
- **Humidity**

WEATHER-RELATED IMPACTS

- **Tropical Storms and Ice Storms**
- **Coastal Flooding and Storm Surges**
- **Freeze-Thaw Cycles**
- **Reduced Visibility**
- **Drought** – *wildfire hazard*
- **Heat Stress**

Climate change affects the frequency, duration and severity of weather-related impacts

Space Transportation Sensitivities

Infrastructure

- **Planning and Design**
- **Construction**
- **Maintenance**

Space Exploration Equipment

- **Design** – *reqts. & specs.*
- **Fabrication and Assembly**
- **Maintenance**

Operations

- **Efficiencies** – *launch windows*
- **Mobility**
- **Safety**

Modified from "Climate Change and Transportation: Potential Interactions and Impacts", B. Mills & J. Andrey (2002) http://climate.volpe.dot.gov/workshop1002/mills.pdf

Supply Chain Risks

Figure 4-1

2004 Industrial Processes Chapter Greenhouse Gas Sources

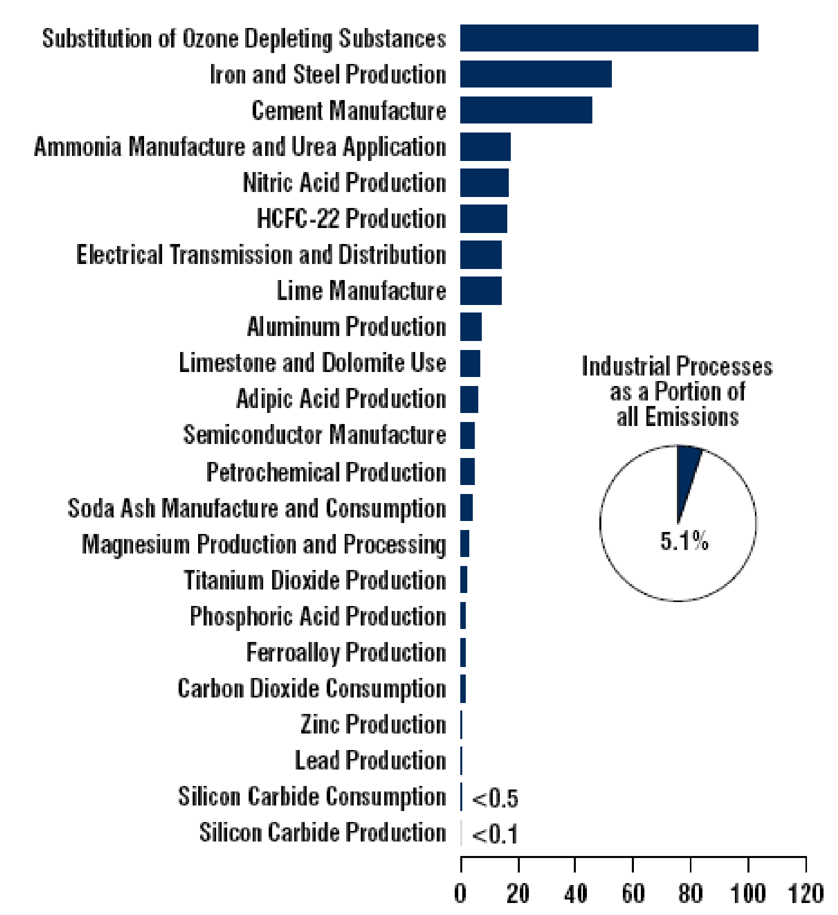


Table 5: Overview of CO_2 emission factors from the production of metals and inorganics

	Input raw materials (%)			Specific CO_2 emissions
	Pet coke	Pitch	Coke/coal	(t CO_2/t product)
Use of carbon electrodes				
Primary aluminium	84	16		1.55
Electric steel	70	30		0.01
White phosphorus	72	28		0.18
Ferrosilicon	72	28		0.17
Silicon metal	85	15		0.36
Calcium silicon	85	15		0.32
Ferromanganese	72	28		0.04
Silicomanganese	72	28		0.09
Ferrochromium	72	28		0.06
Ferrochromiumsilicon	72	28		0.11
Magnesium	85	15		0.05
Ferronickel	72	28		0.01
Tin	85	15		0.04
Use of other solid carbon				
White phosphorus	6		94	4.18
Titanium dioxide	100			0.49
Ferrosilicon			100	2.75
Silicon metal	100			4.49
Calcium silicon			100	2.39
Ferromanganese			100	1.75
Silicomanganese			100	1.57
Ferrochromium			100	1.57
Ferrochromiumsilicon			100	2.71
Lead			100	0.64
Ferronickel			100	1.35
Tin			100	1.08
Zinc			100	0.43
Calcium carbide	15	5	80	1.10
Silicon carbide	100			2.30

US EPA (2006) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2004

M.L. Neelisa, *, M. Patela and D.J. Gielenb (SEPTEMBER 2003) DRAFT VERSION “Modeling non-energy use CO2 emissions and carbon storage with the Non-energy use Emission Accounting Tables (NEAT)”

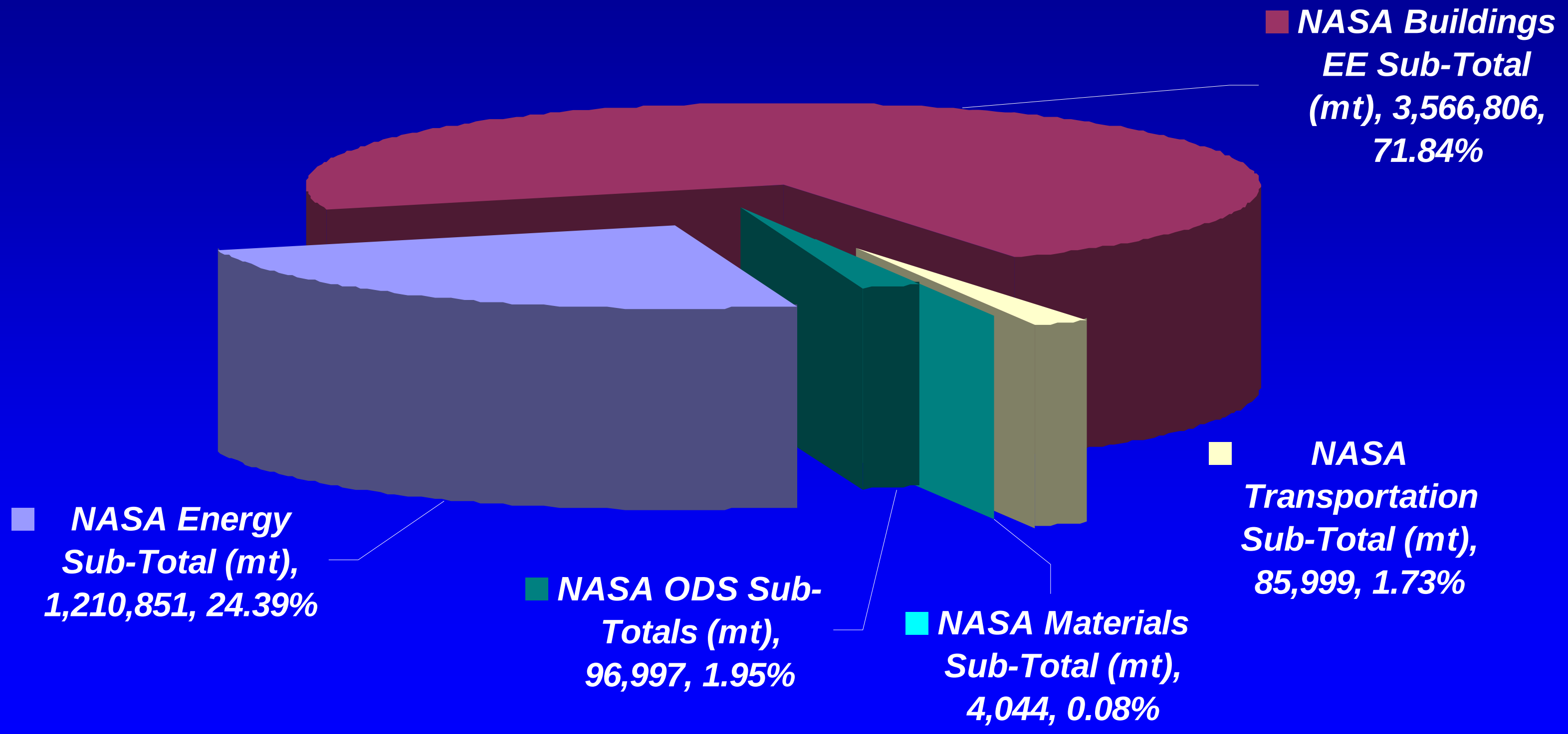
Risk Effects of Climate Change on NASA

- **Regulatory Risk:** Regulatory impact of Greenhouse Gas emissions on NASA operations and activities
- **Supply Chain Cost Risk:** Vulnerability of NASA suppliers in terms of higher component and energy costs passed on to NASA (80-90% of NASA's budget is spent on acquisitions); Aerospace Industry relies on suppliers of steel, aluminum, and plastics that will be affected by emissions regulations
- **Product & Technology Risk:** Economic viability of NASA suppliers of commercial aerospace products & technology that will be geographically vulnerable to application of varying local regulatory schemes
- **Physical Risk:** NASA Center risks to sea level change, and change in frequency and intensity of extreme events (e.g., hurricanes)

Modified by I. S. Higuchi from: J. Lash & F. Wellington (2007) "Competitive Advantage on a Warming Planet" Harvard Business Review (March) pages 95-102.

EXAMPLES OF REDUCING NASA's RISK EXPOSURE: MITIGATION ACTIONS

NASA 2005 Greenhouse Gas Equivalents Emissions By Category



NONENERGY EMISSION REDUCTION

Halocarbons	
Not-in-kind	Modify or replace existing equipment to use non-CFC materials as cleaning and blowing agents, aerosols, and refrigerants.
Conservation	Upgrade equipment and retrain personnel to improve conservation and recycling of CFC materials.
HCFC/HFC-Aerosols, etc.	Substitute cleaning and blowing agents and aerosols with fluorocarbon substitutes.
HFC-Chillers	Retrofit or replace existing chillers to use fluorocarbon substitutes.
HFC-Auto Air Conditioning	Replace existing automobile air conditioners with equipment that utilizes fluorocarbon substitutes.
HFC-Appliance	Replace all domestic refrigerators with those using fluorocarbon substitutes.
HCFC-Other Refrigeration	Replace commercial refrigeration equipment such as that used in supermarkets and transportation with that using fluorocarbon substitutes.
HCFC/HFC-Appliance Insulation	Replace domestic refrigerator insulation with fluorocarbon substitutes.
Agriculture (domestic)	
Paddy Rice	Eliminate all paddy rice production.
Ruminant Animals	Reduce ruminant animal production by 25%.
Nitrogenous Fertilizers	Reduce nitrogenous fertilizer use by 5%.
Landfill Gas Collection	Reduce landfill gas generation by 60 to 65% by collecting and burning in a flare or energy recovery system.

National Research Council (1992) Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base

ODS Global Warming Potential (GWP) Contributors

- NASA's FY 2005 ODS releases:
  CO2 equivalent of 97,604 metric tons
- In terms of ODSs, NASA's biggest GWP contributor:
  CFC-12
- In terms of ODSs, NASA's top five releases come from:
  HCFC-141b, HCFC-22, CFC-12, CFC-113, HCFC-225CB
- In terms of ODSs, NASA's top five GWP contributors are:
  CFC-12, CFC-113, HCFC-22, HCFC-141b, CFC-115

TABLE 6.2 Comparison of Selected Mitigation Options in the United States

Mitigation Option	Net Implementation Cost[a]	Potential Emission[b] Reduction ($t\ CO_2$ equivalent per year)
Building energy efficiency	Net benefit	900 million[c]
Vehicle efficiency (no fleet change)	Net benefit	300 million
Industrial energy management	Net benefit to low cost	500 million
Transportation system management	Net benefit to low cost	50 million
Power plant heat rate improvements	Net benefit to low cost	50 million
Landfill gas collection	Low cost	200 million
Halocarbon-CFC usage reduction	Low cost	1400 million
Agriculture	Low cost	200 million
Reforestation	Low to moderate cost[d]	200 million
Electricity supply	Low to moderate cost[d]	1000 million[e]

NOTE: Here and throughout this report, tons are metric.

[a]Net benefit = cost less than or equal to zero
Low cost = cost between \$1 and \$9 per ton of CO_2 equivalent
Moderate cost = cost between \$10 and \$99 per ton of CO_2 equivalent
High cost = cost of \$100 or more per ton of CO_2 equivalent

[b]This "maximum feasible" potential emission reduction assumes 100 percent implementation of each option in reasonable applications and is an optimistic "upper bound" on emission reductions.

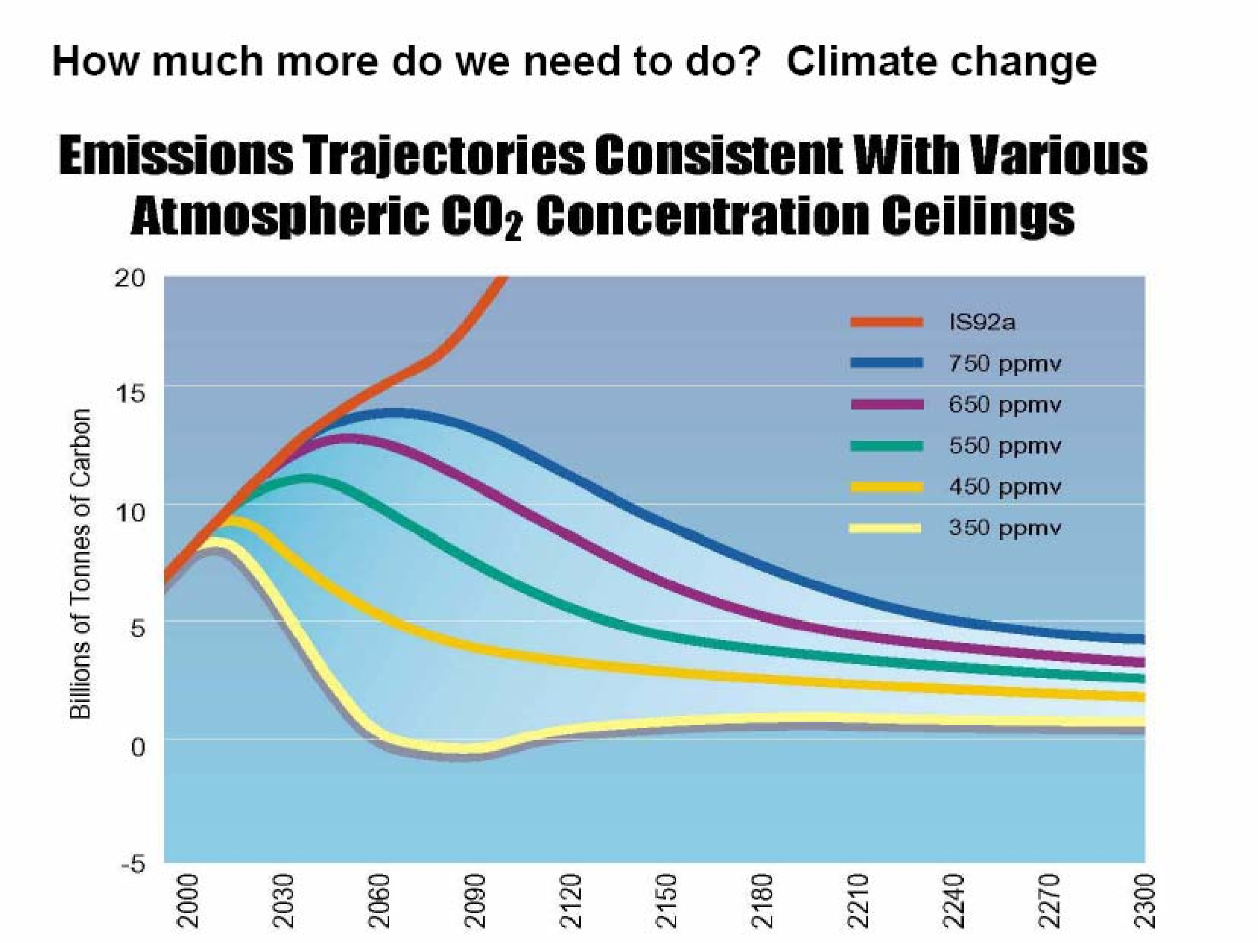
[c]This depends on the actual implementation level and is controversial. This represents a middle value of possible rates.

[d]Some portions do fall in low cost, but it is not possible to determine the amount of reductions obtainable at that cost.

[e]The potential emission reduction for electricity supply options is actually 1700 Mt CO_2 equivalent per year, but 1000 Mt is shown here to remove the double-counting effect (see p. 62 for an explanation of double-counting).

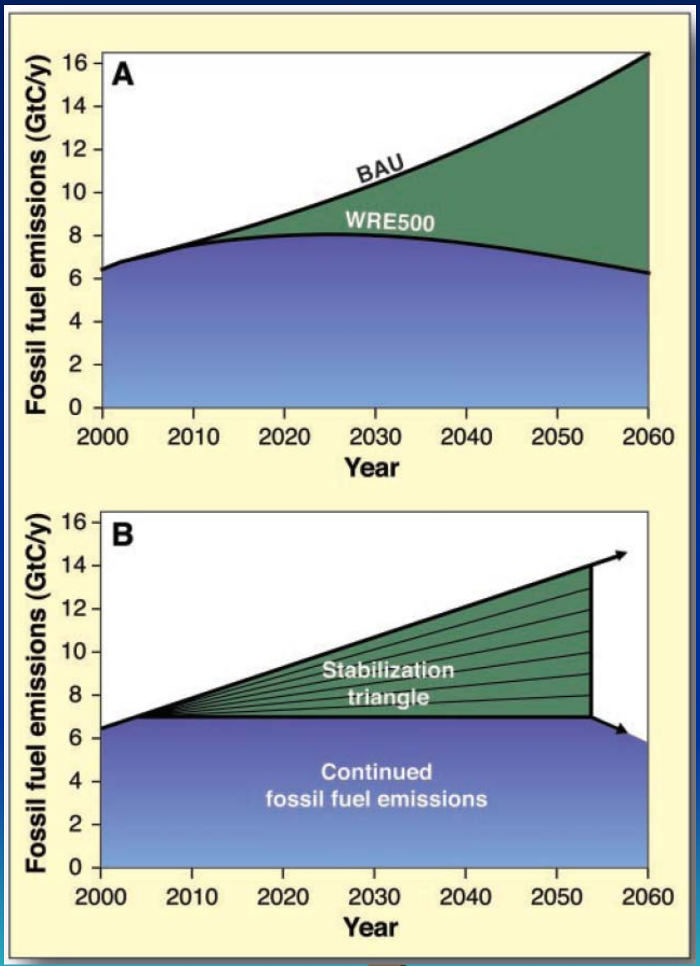
National Research Council (1992) Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base

Mitigation Action: Levels of CO_2 Concentration



J. P. Holdren (2006) AAAS Science & Technology Policy Forum: "The Economic, Environmental, & National Security Challenges of Energy Supply and the Role of Science & Technology in Addressing Them" http://www.aaas.org/spp/rd/Forum_2006/holdren.pdf

Mitigation Actions:



Wedge Summary Table

Category	Technology
Efficiency	**Efficient vehicles** **Reduced use of vehicles** **Efficient buildings** **Efficient baseload coal plants**
Decarbonization of power	**Gas baseload power for coal baseload power** **Capture CO2 at baseload power plant** **Nuclear power for coal power** **Wind power for coal power** **PV power for coal power**
Decarbonization of fuel	**Capture CO2 at H2 plant** **Capture CO2 at coal-to-synfuels plant** **Wind H2 in fuel-cell car for gasoline in hybrid car** **Biomass fuel for fossil fuel**
Forests and agricultural soils	**Reduced deforestation, plus reforestation, afforestation, and new plantations** **Conservation tillage**

S. Pacala & R. Socolow (2004) “Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies”

SCIENCE VOL 305 pages 968-972.

EXAMPLES OF REDUCING NASA's RISK EXPOSURE: ADAPTIVE RESPONSE ACTIONS

NASA and New York City

Adapting New York City's Water System to Climate Change

David C. Major[1], Cynthia Rosenzweig[2], Kate Demong[3], and Christina Stanton[1]
Columbia University Center for Climate Systems Research[1], NASA Goddard Institute of Space Studies[2], and NYC Department of Environmental Protection[3]

In August 2004, the **NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION (NYCDEP)** established the NYCDEP Climate Change Task Force (Task Force) to develop responses to climate change and climate variability. The Task Force, working in partnership with Columbia University's Center for Climate Systems Research (CCSR) and other institutions, serves to ensure that potential impacts of and adaptations to climate change on the New York City (City) water supply and wastewater systems are factored into the Department's long-term strategic and capital planning. In conjunction with its adaptation activities, the Task Force is investigating the development of a greenhouse gas (GHG) emissions management program. The Task Force is an agency-wide endeavor whose members are NYCDEP employees from all bureaus.

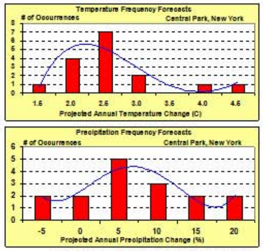
NYCDEP CLIMATE CHANGE TASK FORCE MISSION:

"Ensure that NYCDEP's strategic and capital planning efficiently take into account the potential effects of climate change—sea level rise, higher temperature, increase in extreme events, and changing precipitation patterns—on the City's water supply and wastewater treatment systems".

ADAPTATION ASSESSMENT INCLUDES:

- **Identifying impacts**
- **Applying future climate scenarios:** utilize scenarios to analyze possible impacts for which adaptations are needed
- **Characterizing options:** operations, capital investments, and/or policy
- **Conducting initial screening:** engineering, institutional, regulatory feasibility
- **Linking to capital cycle**
- **Evaluating options:** costs/benefits, ensure no regret adaptations
- **Creating implementation plans:** time scales - short, medium, long-term
- **Monitoring and Reassessing:** use of indicators, continue to refine science

Model-Based Probability for Climate Change in 2050s
New York City
Based upon 8 Global Climate Models*



* Downscaled from the following global climate models: CSIRO, CCCma, GFDL, GISS, HCCPR, CCSR, MPIFM, and NCAR
NASA/GISS Climate Impacts Group

POTENTIAL ADAPTATION EXAMPLES

Bureau of Water Supply (policy and capital investment): **Modify dam infrastructure to allow for water releases to create a short-term void in anticipation of a storm event.**
Photo of Croton Falls spillway.

Bureau of Water and Sewer Operations (operations): **Inventory existing tide gates; identify priority locations most vulnerable to sea level rise and storm surges to support long-term maintenance and possible future installation programs.**
Photo of NYCDEP tide gate.

Bureau of Wastewater Treatment (capital investment): **Construct Flood Walls in response to sea level rise and associated storm surge levels.**
Photo of treatment tanks overflowing at a Bronx WPCP during March 2001 storm; unusually high tidal elevations blocked discharge of treated sewage into East River and caused back-up.

CLIMATE CHANGE VARIABLES IMPORTANT TO NYCDEP

Surface Air Temperature (min, max, mean): There is a long-term warming trend in the New York Metropolitan Region, with **annual mean temperature of the region rising at a rate of 0.014 ºC/ year** for a total cumulative temperature change of roughly 1.4 ºC over the course of the last century.

Precipitation: Over the past century, **annual precipitation in the region has increased by ~2.5 cm.**

Sea Level Rise: Global sea level is rising at a rate of ~1.7 mm/year, while **sea level rise for the NY Metro Region rate is ~2.6 mm/year** due to local subsidence.

Extreme Events (Storms, Floods, Droughts): One of the greatest impacts facing the NYCDEP is **stronger and more frequent hurricanes and Nor'easters threatening system infrastructure and quality of the water supply.**

Models & Forecasts
- Global Climate Models (GCMs)
- Regional Climate Models (RCMs)
- Greenhouse Gas Emission Scenarios
- Sea Level Rise
- Storm Surge
- Watershed & Terrestrial Models
- Drought & Flood Indices

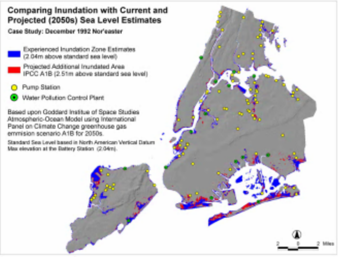
Sea Level Rise Projections -- New York Metropolitan Region, cm

Time Period	Current Trend* (cm)	IPCC GHG Emission Scenario B1 (cm)	IPCC GHG Emission Scenario A1B (cm)
2020s	8.3	17.6	11.2
2050s	16.6	35.7	47.2
2080s	27.7	79.3	97.7

Based upon Goddard Institute of Space Studies Atmospheric-Ocean Global Climate Model Sea level rise data for decadal means relative to 1990-1999 mean.
* Due to both thermal expansion and local subsidence.

Source: Columbia Center for Climate Systems Research

Coordinated Science Example
- Interdisciplinary research project on coastal flooding.
- Uses sea level rise forecasts with storm surge & elevation models to analyze impact on NYCDEP coastal facilities.
- Initial runs of the sea level model using a low-level (B1) and mid-level (A1B) GHG emissions scenarios suggests sea level rise increase in the 2050s may range from 16.6 to 47.2 cm (6.1 to 18.8 in) in comparison to the 1990s decadal mean.



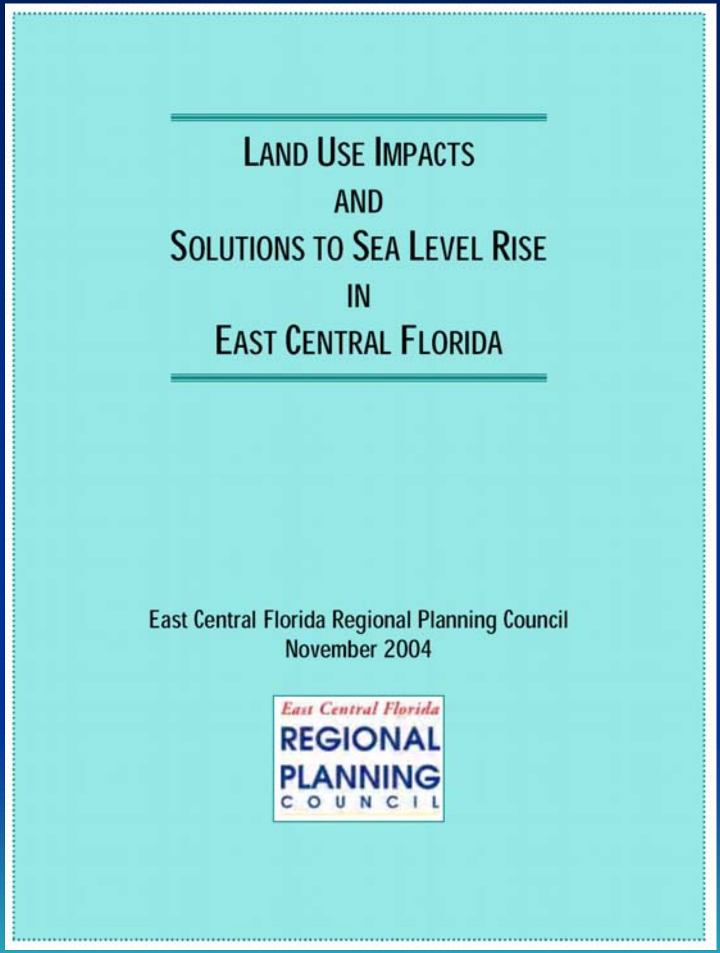
MITIGATION

The Task Force's mitigation activity serves to aid in the development of a GHG emissions management program. Efforts focus on producing a GHG mitigation assessment framework and process, and an initial agency-wide GHG inventory conducted in cooperation with the city-wide GHG inventory.

References: NYC Department of Environmental Protection, www.nyc.gov/dep; Columbia Center for Climate Systems Research, www.ccsr.columbia.edu; Stony Brook Storm Surge Group, http://msrc.sunysb.edu; and HydroQual Inc., www.hydroqual.com

November 2005

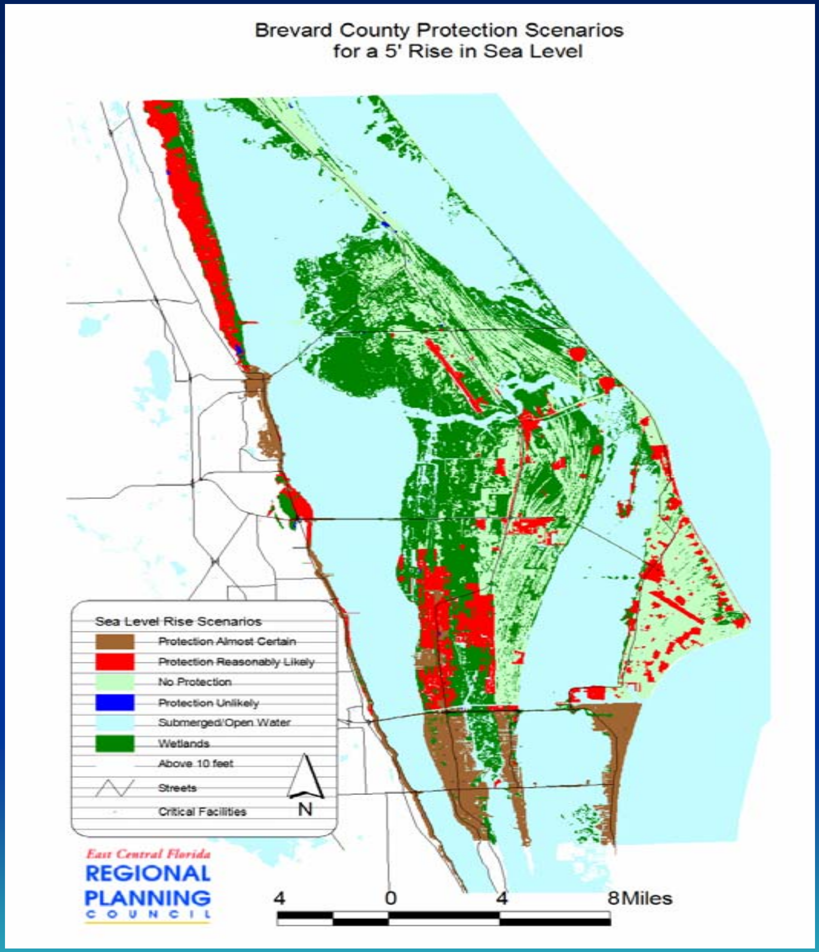
Land Use Planning: Brevard County, FL



LAND USE IMPACTS
AND
SOLUTIONS TO SEA LEVEL RISE
IN
EAST CENTRAL FLORIDA

East Central Florida Regional Planning Council
November 2004

East Central Florida
REGIONAL
PLANNING
COUNCIL



Reducing NASA's Risk Exposure to Climate Change

- STEP 1- Quantify NASA's Greenhouse Gas Situation:
  - CO_2 equivalents = 4,964,697 mT
- STEP 2 - Assess NASA's Climate Change Risks:
  - NASA's hurricane risk exposure has been studied (NASA-HQ Facilities Engineering & Real Property Division)
  - A generalized assessment of NASA's climate change risk exposure is under way (NASA-HQ Environmental Management Division)
- STEP 3 - Adapt NASA's Climate Change Responses to the Risks: ??? (New York City – NASA Goddard Institute of Space Studies)

Modified by I. S. Higuchi from: J. Lash & F. Wellington (2007) "Competitive Advantage on a Warming Planet" Harvard Business Review (March) pages 95-102.